Redshifting the LSST gold sample

Anže Slosar

Brookhaven National Laboratory

October 1, 2015

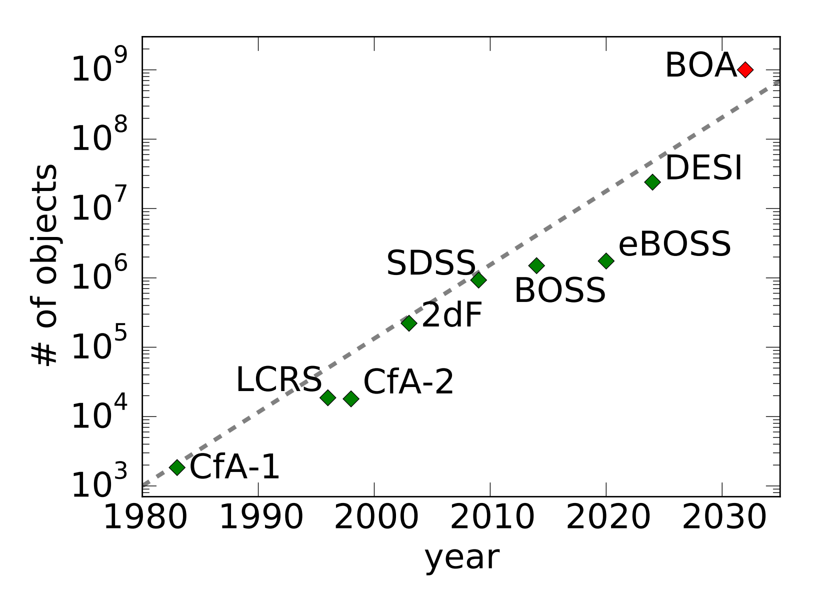
Outline

- Motivation for a Billion Object Apparaturs
- What could and what won't work
- Where do we stand:
  - HETDEX
  - MUSE
  - DESI
- Kyle Dawson from Utah helped develop these ideas

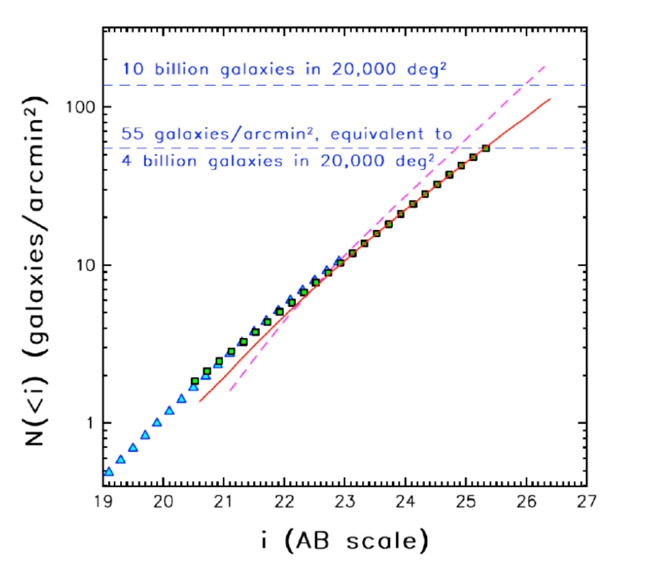
2025

- DESI on the north, LSST on the south
- DESI is state of the art spectroscopic, LSST state of the art photometric
- LSST will have 4 billion objects in the catalog, but its scientific reach likely limited by photo-z errors
- It is natural to:
  - Follow LSST with a spectroscopic survey
  - Use LSST as to set targetting catalog
  - Be an order of magnitude bigger than DESI

1 billion objects in 2032



1 billion objects in 2032



LSST GOLD sample

Science with 1 billion galaxies

- AMAZING!
- I could bullshit on demand for 30 mins on this, but AMAZING!
- Instead, let's focus on seeing if it is possible ...

Basic sums

- 1 billion objects is about 13 per square arcmin to $i < 23.5$
- To redshift an $i = 23.5$ object on a 8m telescope takes 2-4 hours with 75-95% efficiency (see later, biggest uncertainty)
- DESI gets ∼1400hours per year (after the bright star nearby and the weather are accounted for)
- For a 5 year survey at 3 hours per object need 4.2×10^5 multiplexing of spectra, call that 500,000 object spectrograph

Basic sums 2

- At 500,00 objects, with $\sim$ 15 per arcmin, need 9.2 square degrees, or 3.4 degree FOV, same as LSST.
- This is pretty aggressive, since the f ratio of LSST does not suit spectroscopy, but there is some lee-way:
  - We assumed all sources to be at the limiting mag for integration time calculation
  - We assumed 5yr rather than 10yr survey
  - Can also trade fewer fibers, smaller FOV for a bigger mirror

DESI

- 5000 fibers on fiber-positioners at 700/square deg
- 10×500 fiber, 3 arm spectrographs
- 3 4kx4k CCDs, or 48 Mpixel
- 360nm-980nm, $R = 2000 - 5500$

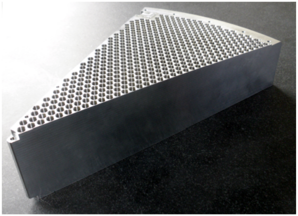


Fig. 3. An individual petal, containing 507 positioner holes. 10 of this petals will conform the entire DESI focal plate structure (Image Credit: IAC).

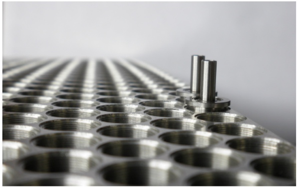
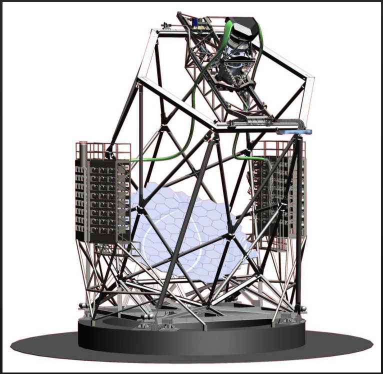


Fig. 4. Detail of two dummy positioners installed in two holes (Image Credit: IAC).

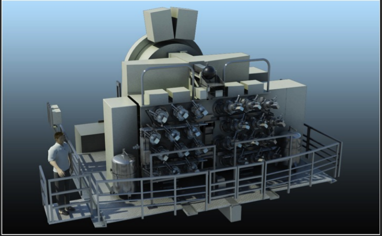
HETDEX

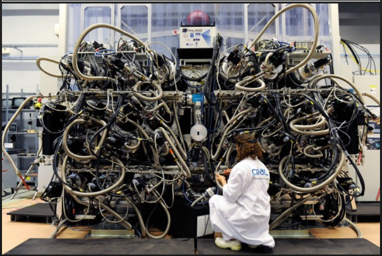
- 33600 fibers at 1.5 arc sec IFU
- 75 units taking 448 fibers each
- 2x 2k x 2k CCDs
- 350nm-550nm, $R \sim 700$



MUSE

- 24×48 slicings for 1152 spectra
- 0.2 arc sec sampling (telescopes uses AO)
- One 4kx4k CCD per 48 spectra
- 360nm-93nm, $R \sim 2000 - 4000$

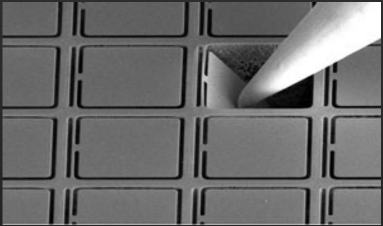


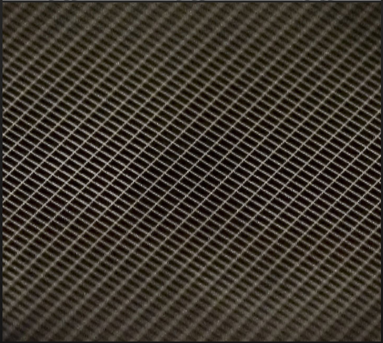


You do get eaten!

Microshutter arrays

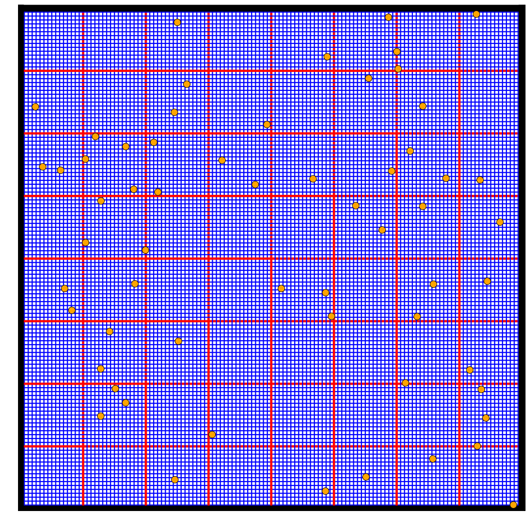
- Developed for JWST
- $100\mu m$ pixels, 128x128 arrays typical
- At typical plate scale of 100μm per arcsec, these are approximately one arcsec





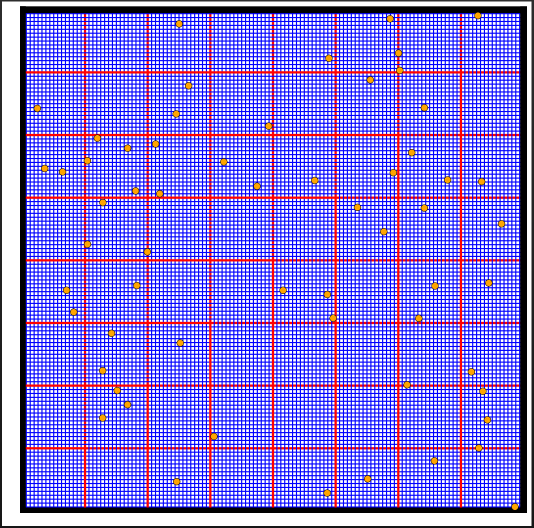
A possible concept

- 13 object / arcmin is one per 16x16 arc sec
- A 16x16 arcsec region can be coupled with a lenslet to a single fiber
- Lenslet is 1.6mm in size
- The entire unit is 64 fibers at 1.3cm, pack them into 4x4 to get 1024 fiber 5.5x5.5cm modules
- Link 500 modules to 500 spectrographs
- Opening shutters where the source falls filters sky-noise
- There are fill-factor corrections $O(10\%)\ldots$



A possible concept

- Sources are not uniformly distributed
- Empty fibers can be used as sky fibers and to look for Lyman-α emission
- Cells with multiple sources can switch the source between exposures
- It might also be possible to integrate two source at the same time and solve in software, but note no SNR advantage
- Liouville's theorem: is this is actually doable?



What kind of spectrograph?

- It would take 1000 DESI spectrographs (!)
- The pixel count at DESI density is around 48 GPix (c.f 0.48Gpix for current DESI, 3.5 Gpix for LSST)
- Industrial scale production would be neccessary: HETDEX attempted this with limited success, but labs should be better at it
- A fourth infrared channel anyone?

Targetting and integration times

- Difficult to project, need a real simulator
- Deep survey in VVDS got $i < 24$ in 4.5 hrs at $R = 230$ with 90% success rate, corresponding to 2hrs for $i < 23.6$ in VLT: JN tells me this is unrealistic:

  > *If you restrict to as stringent a definition of success as DEEP2 generally uses ($< 5\%$ chance of being wrong, and even that level of failure is problematic for cosmology) the VVDS-deep success rate for galaxies is 43%, not 90%*

- DEEP2 got 75% success and a 1-few hours of pointing

Cost and trade-offs

- A simple cost-tradeoff should be made between cost of mirror, cost of fibers and cost of silicon: need a more serious concept for even attempting that
- Current cost is \$1 mil per 1000 fiber spectrograph
- Extrapolate from current:
  - eBOSS, 1.5 million spectra for $\sim$\$24 million = 16\$/spectrum
  - DESI, 35 million spectra for $\sim$100 million = 2.8\$/spectrum
  - BOA, 1 billion spectra for $\sim$?? million = ?? \$/spectrum

Next steps…

- Should study the basic building blocks: microshutter+lenslet+fiber
- A 64 fiber unit could be demonstrated on SDSS telescope on a star cluster
- Make less half-baked attempt to study SNR using more precise knowledge of targe source classes ([OII] emitters, QSOs, LRGs,etc.)
- Develop tools to study trade-offs realistically